UNCLASSIFIED

AD NUMBER
AD361407
CLASSIFICATION CHANGES
TO confidential
FROM secret
AUTHORITY
30 Jun 1977 per Grp-3 document marking

THIS PAGE IS UNCLASSIFIED

CONFIDENTIAL

AD 361407

DEFENSE DOCUMENTATION CENTER

FOR

SCIENTIFIC AND TECHNICAL INFORMATION

CAMERON STATION, ALEXANDRIA, VIRGINIA

MEMORANDUM
RM-4296-PR
JUNE 1965

SYSTEM COSTS FOR STRATEGIC PENETRATOR SYSTEMS USING SUBMERSIBLE AND CONVENTIONAL AIRCRAFT (U)

Albert J. Tenzer, A. Frank Watts and John J. Kermisch

PREPARED FOR:
UNITED STATES AIR FORCE PROJECT RAND

The RAND Corporation
SANTA MONICA • CALIFORNIA

SECRET

MEMORANDUM
RM-4296-PR
JUNE 1965

SYSTEM COSTS FOR STRATEGIC PENETRATOR SYSTEMS USING SUBMERSIBLE AND CONVENTIONAL AIRCRAFT (U)

Albert J. Tenzer, A. Frank Watts and John J. Kermisch

This research is sponsored by the United States Air Force under Project RAND—Contract No. AF 49(638)-700—monitored by the Directorate of Operational Requirements and Development Plans, Deputy Chief of Staff, Research and Development, Hq USAF. Views or conclusions contained in this Memorandum should not be interpreted as representing the official opinion or policy of the United States Air Force.

The RAND Corporation
1700 MAIN ST • SANTA MONICA • CALIFORNIA • 90406

SECRET

PREFACE

This Memorandum documents the cost analysis performed as part of a RAND study of possible mission applications of submersible aircraft. These applications have been discussed in RM-4183-PR, Submersible Aircraft: Potential Missions, Selected System Operations, and Costs (U), Roger P. Johnson, Henry P. Rumble, and Albert J. Tenzer, The RAND Corporation, November 1964 (Secret).

Related questions of technical feasibility and performance capabilities of submersible aircraft are discussed in the following previous publications: RM-3683-PR, The Submersible Aircraft: Design Feasibility and Performance Calculations (U), Roger P. Johnson and Henry P. Rumble, The RAND Corporation, August 1963 (Secret); and RM-4180-PR, Submersibly Moored and Submersible Aircraft: Comparative Design and Parametric Performance Analysis (U), Roger P. Johnson and Henry P. Rumble, The RAND Corporation, October 1964 (Secret).

SUMMARY

The cost analysis documented in this Memorandum was performed in support of a RAND study of submersible aircraft.

A cost analysis of strategic weapon systems has been made comparing aircraft weapon systems capable of undersea operations with land based systems. The comparison has been done in an analytical framework using an "equal effectiveness" approach. In estimating the cost of weapon systems using submersible aircraft, much uncertainty exists at this time regarding operation in the underwater environment. This uncertainty has been in part handled by a cost-sensitivity analysis. However, because of time constraints, it has been necessary to make some arbitrary assumptions about key operational parameters.

Costs have been estimated for eighteen systems based on three types of penetrator aircraft: an advanced manned strategic aircraft (AMSA); a penetrator carried as a parasite by a long endurance aircraft (LEA); and a submersible penetrator aircraft (SPA). The main difference between the systems lies in the type of penetrator aircraft or the type of refueling support aircraft (or other support aircraft). Nine systems had AMSA penetrators supported by land-based or submersible tanker aircraft. Two systems used parasite penetrators. Seven systems had submersible penetrator aircraft.

The costs, estimated for a force adequate to provide 100 alert penetrators on station in a state of operational readiness, ranged from $5 billion to $22 billion.

CONTENTS

LIST OF FIGURES

LIST OF TABLES

I. INTRODUCTION

An analysis of the cost-effectiveness of alternative military forces or weapon systems may use one of two approaches: either beginning with a fixed budget and attempting to determine the most effective force mix or weapon system that can be obtained within that budget, or beginning with a specific military job or mission and then estimating the cost of the alternative methods of doing it.

The approach used in this study was the "fixed effectiveness" approach. Having described the job to be done in terms of a strategic mission, we examined the estimated costs of three major weapon system approaches, assumed to be equally capable of performing the mission. The criterion used for comparison in this study was the cost of a force adequate to provide, at all times, 100 penetrators in a state of operational readiness (hereafter referred to as "alert penetrators'). This method enabled us to deal with some problems of uncertainty about the operations of the equipment in an underwater environment.

Although the primary focus of interest in this study was submersible aircraft, it was incumbent upon us to examine such aircraft within a context of other weapon systems that could also carry out the postulated mission. To this end, three types of penetrator aircraft have been compared: an advanced manned strategic aircraft (AMSA); a parasite carried airborne by a long endurance aircraft (LEA); and a submersible penetrator aircraft (SPA). These three types of penetrator aircraft, provided with an assortment of different kinds of support equipment, and with varying basing, mobility, and other operational specifications, were configured into eighteen penetrator systems, which are discussed in the following sections. A system description, the equipment requirements, and a summary of costs of these systems are presented in Table 1.

The mission that all of the systems would fulfill is a strategic precision strike mission, to penetrate 1000 miles into the Sino-Soviet land mass at low altitude (see Fig. 1) and deliver a payload of 10,000 lb of air-to-surface missiles. All aircraft here are considered to have the same penetration profile and would carry the same armament and avionics.

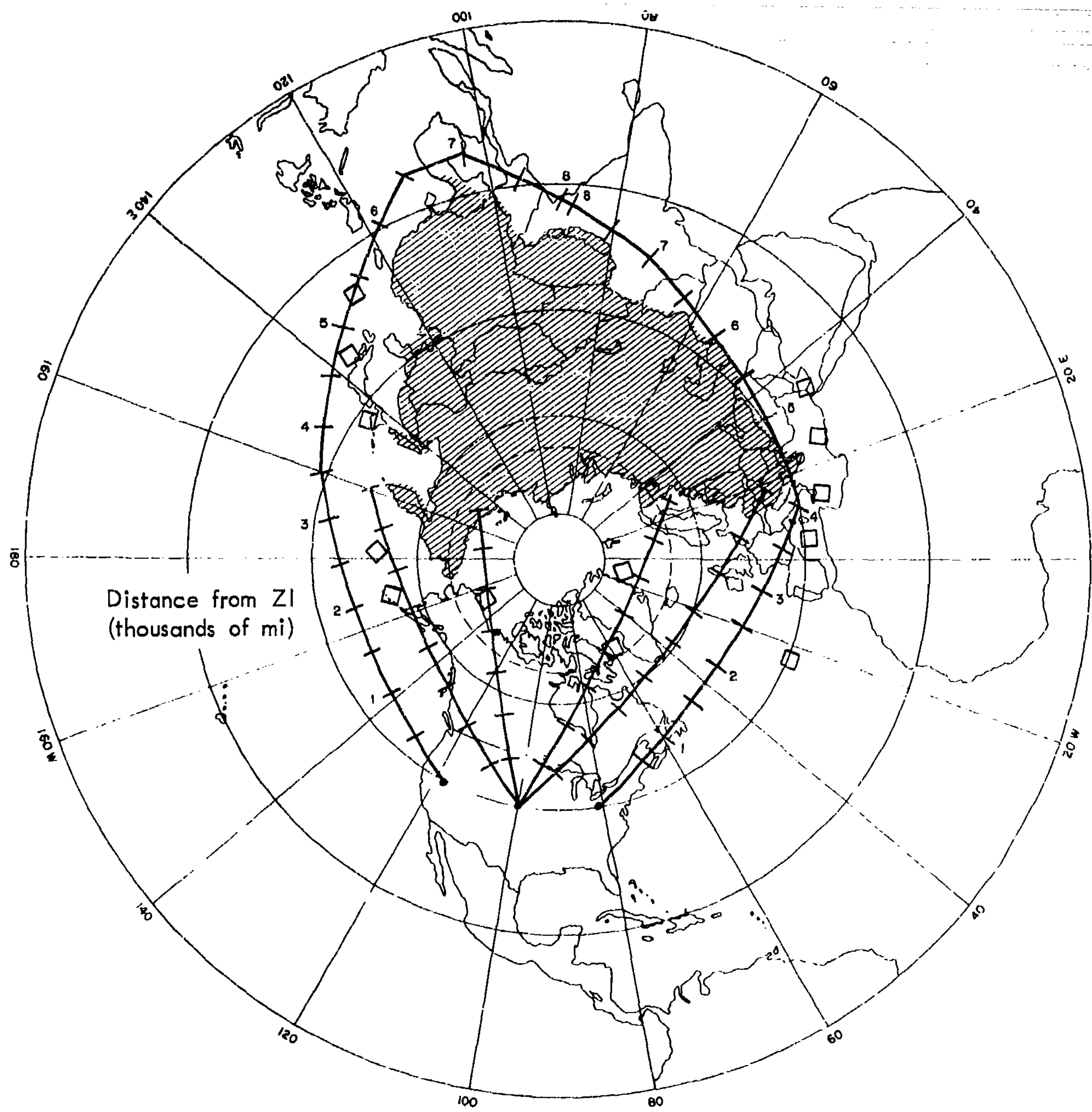
Table 1

SYSTEM DESCRIPTION REQUIREMENTS AND COSTS FOR 18 STRATEGIC SYSTEMS
(ESTIMATED FOR A FORCE SIZE PROVIDING 100 ALERT PENETRATORS)

	System Description									Unit Equipment Requirements				
	Penetrator													
System	Designation	Basing	Alert Type	Alert %	Designation	Basing	Alert Type	Alert %	System Mobility*	Penetrator Aircraft	Tanker Aircraft	Submersible Platforms	Submersible Pusher Tugs	Force Cost (billions of 1964 dollars)
1	AMSA	Land	Ground	50	KC-AMSA	Land	Ground	50	N/A	200	190	N/A	N/A	12.9
2	AMSA	Land	Ground	50	Mod. KC-135	Land	Ground	50	N/A	200	198	N/A	N/A	10.3
3	AMSA	Land	Ground	50	Submersible Tanker Aircraft	Underwater	Underwater	33-1/3	High	200	328	40	30	22.5
4	AMSA	Land	Ground	50	Submersible Tanker Aircraft	Underwater	Underwater	50	High	200	213	31	26	19.3
5	AMSA	Land	Ground	50	Submersible Tanker Aircraft	Underwater	Underwater	66-2/3	High	200	164	25	22	17.7
6	AMSA	Land	Ground	50	Submersible Tanker Aircraft	Underwater	Underwater	33-1/3	Low	200	328	40	6	19.5
7	AMSA	Land	Ground	50	Submersible Tanker Aircraft	Underwater	Underwater	50	Low	200	218	31	6	17.2
8	AMSA	Land	Ground	50	Submersible Tanker Aircraft	Underwater	Underwater	66-2/3	Low	200	164	25	6	16.0
9	AMSA	Land	Ground	50	Submersible Tanker Aircraft	Land-based flyout and submersion	Ground	50	Fixed Platform	200	182	25	N/A	15.3
10	Parasite	Land	Airborne	75	No refueling support required. Parasite aircraft is carried by an LEA.				N/A	134**	N/A	N/A	N/A	8.5
11	Parasite	Land	Ground	50					N/A	200**	N/A	N/A	N/A	7.2
12	SPA	Underwater	Underwater	33-1/3	Manned Underwater Platform				High	375	N/A	28	21	12.9
13	SPA	Underwater	Underwater	50	"				High	250	N/A	21	19	10.3
14	SPA	Underwater	Underwater	66-2/3	"				High	188	N/A	17	17	8.4
15	SPA	Underwater	Underwater	33-1/3	"				Low	375	N/A	28	9	11.8
16	SPA	Underwater	Underwater	50	"				Low	250	N/A	21	9	9.2
17	SPA	Underwater	Underwater	66-2/3	"				Low	188	N/A	17	9	7.7
18	SPA	Land-based flyout and submersion	Ground	50	Unmanned Underwater Platform				Fixed platform	200	N/A	25	N/A	5.5

*Applicable only to systems using submersible aircraft.

**Number represents requirement for units comprising one Parasite and one LEA.



☐ Desirable locations for tanker refueling

Fig. 1—Strategic-bomber paths to Sino-Soviet-bloc target system for minimum target-penetration distances

II. DESCRIPTION OF ALTERNATIVE PENETRATOR SYSTEMS AND CONCEPTS OF EMPLOYMENT

Using as a basis the three types of penetrator aircraft, the advanced manned strategic aircraft, the parasite, and the submersible penetrator aircraft, eighteen systems have been postulated. Systems 1 through 9 have AMSA penetrators supported by either land-based (Systems 1 and 2) or submersible (Systems 3 through 9) tanker aircraft. Systems 10 and 11 have parasite penetrators carried airborne by long endurance aircraft. Systems 12 through 18 have SPA penetrators. The peacetime operational assumptions for all systems are presented in Table 2.

Table 2

PEACETIME OPERATIONAL ASSUMPTIONS FOR THREE PENETRATOR AIRCRAFT

	Aircraft		
Assumptions	AMSA	Parasite	Submersible Penetrator
Initial occupancy date	1975	1975	1975
Crew ratio	2.0	2.0	2 0
Aircraft per base	15	15	N.A.
Alert per cent			
Airborne		75	
Ground	50	50	
Underwater			33-1/2 to 66-2/3
Response time (min)	15	15	15
Flying hours (per aircraft/yr)	650	650	650
Payload weight (lb)	10,000	10,000	10,000
Number air-to-surface missiles	8	8	8

The essential difference within each major grouping is either the type of refueling support equipment, the mobility of the refueling support equipment, or the degree of uncertainty as to how well the submersible equipment will perform in its underwater environment.

The mobility of the refueling support equipment is important because it may affect the survivability of the submersible systems. Moving the underwater platforms with their moored aircraft may be necessary to prevent their locations from becoming known, and therefore vulnerable, to an enemy. To take care of this problem, two levels of mobility have been predicated: "high mobility," in which each forwardly deployed underwater platform has a pusher submarine to move it, or "low mobility," where one pusher submarine is located in each forward area to move in some sequence all platforms in that area.

The problem of uncertainty about the submersible systems may be divided into two categories. The first has to do with the ability of the submersible aircraft and the personnel to cope with the problems of the underwater environment. This has been arbitrarily called "peace-time operational uncertainty."

The second category might then be termed "wartime operational uncertainty." If, for example, ten submersible penetrators, moored underwater upon a platform, are called upon to surface and commence their strategic missions within 15 minutes, it is unlikely that all would, in fact, be able to respond as desired.

Faced with these problems, we have provided for the second category, wartime operational uncertainty, by arbitrarily deciding that only eight out of ten submersible penetrators on station (and five out of six submersible tankers) would be able to perform their wartime missions within the specified response time.

The peacetime operational uncertainty, which is really the more basic question of equipment and personnel endurance, we have elected to treat parametrically within what seemed a reasonable range. The actual method used was as follows:

If it were possible to have a system capable of remaining underwater indefinitely in a state of operational readiness (with both equipment and personnel subject to no deterioration, needing no maintenance, always "on alert"), then we would consider such a system to have 100 per cent alert capability. The actual percentage of alert capability is important because it determines the number of backup aircraft and other equipment required for the system. A system with 100 per cent alert capability would require, in order to guarantee 100 operationally ready penetrators, no backup aircraft at all (excluding command support or attrition aircraft). A system that has only 50 per cent alert capability because its aircraft or personnel can remain operationally ready only half time, and require maintenance, training, and/or rest for an equal period, would require 100 backup aircraft and equipment for each 100 aircraft on alert (again excluding command support or attrition aircraft).

To provide for the sensitivity of the system costs to this area of uncertainty, we have estimated the costs of systems using submersible equipment for each of three levels of alert capability: 66-2/3 per cent (assuming a high degree of equipment reliability and human endurance), 50 per cent, and 33-1/3 per cent (assuming a low degree of equipment reliability and human endurance). The system cost implications of this uncertainty are illustrated in Fig. 2.

The present Polaris-carrying nuclear submarine provides a background for the examination of peacetime operational uncertainty. Currently these submarines remain on station roughly 33-1/3 per cent of their time, and thus they require a backup of two submarines for each one on station. This requirement exists because of necessary maintenance, training, travel to and from station, personnel limitations, etc. Since this is the alert capability of the Polaris submarine, it was taken as a point of reference for the submersible aircraft discussed in this study and formed one limit of the range of system capability examined.

The nuclear submarine also provides an analogy in the area of wartime operational uncertainty. Each submarine carries 16 Polaris missiles, which are intended to be launched within a specified time after H hour. Since the reliability of any equipment is subject to some uncertainty, it must be assumed that not all the Polaris missiles will be capable of being launched within the specified time. The same assumption was applied to the launching of the submersible aircraft from their platforms.

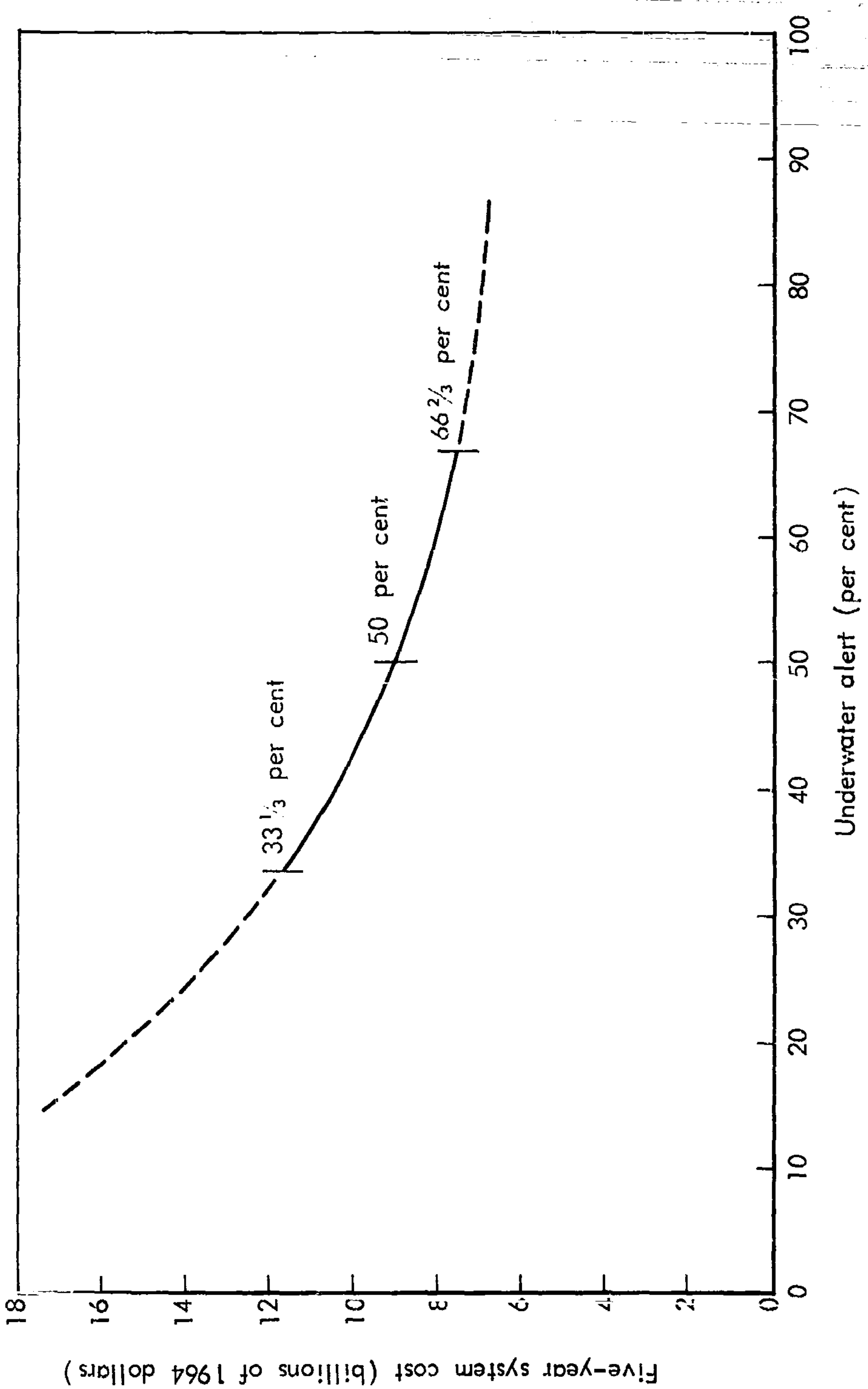


Fig. 2—Cost versus underwater alert capability—SPA (low mobility)

The effect of the alert percentage on the system equipment requirements will be evident in the more detailed calculations that follow, but one general point may well be made here. As the alert percentage decreases, implying a requirement for more backup aircraft (without changing the number of aircraft on station), the weapon system costs increase.

THE ADVANCED MANNED STRATEGIC AIRCRAFT

The first of the three penetrator aircraft to be discussed is the AMSA, which has been considered as a possible successor to the B-52. No firm AMSA design has as yet been decided on, but the technical characteristics of the AMSA as used in this study are as follows:

1.	Length	148 ft
2.	Wing span	143 ft
3.	Material	Aluminum
4.	Number of engines	4 turbofan
5.	Gross weight	375,000 lb
6.	AMPR weight	102,000 lb
7.	Maximum speed	Mach 2.5
8.	Maximum thrust per aircraft	112,000 lb
9.	Fuel and payload	237,000 lb
10.	Wing loading	184 lb sq ft
11.	Variable swept wing	Yes
12.	Laminar flow (wing)	No

It is assumed that the AMSA would become operational in the mid-1970's, replacing the phased-out B-52's; would be located on bases within the Continental U.S.; and would be similar to the B-52 in manning, maintenance, deployment, and peacetime flying operations.

Nine weapon systems have been postulated using the AMSA aircraft, with land- or water-based refueling support. In each of the nine systems the AMSA penetrator would be land based on a 50 per cent ground alert status, and would fly 650 annual flying hours per aircraft with a crew of four. The nine systems are as follows:

1. AMSA penetrator supported by land-based AMSA type tanker also on 50 per cent ground alert.
2. AMSA penetrator supported by land-based modified KC-135 tanker on 50 per cent ground alert.
3. AMSA penetrator supported by submersible tanker on 33-1/3 per cent underwater alert, moored on submerged platforms having high mobility.
4. AMSA supported as in System No. 3, by tanker on 50 per cent underwater alert.
5. AMSA supported as in System No. 3, by tanker on 66-2/3 per cent underwater alert.
6. AMSA supported by submersible tanker on 33-1/3 per cent underwater alert, moored on submerged platform having low mobility.
7. AMSA supported as in System No. 6, by tanker on 50 per cent underwater alert.
8. AMSA supported as in System No. 6, by tanker on 66-2/3 per cent underwater alert.
9. AMSA supported by land-based submersible tanker aircraft on 50 per cent ground alert, which flies out to underwater moored unmanned platform, submerges, and awaits the bomber fleet. In this system the tanker has greatly reduced capability to remain submerged.

The first two AMSA systems (Systems 1 and 2) are supported by conventional land-based tankers. System 1 has an AMSA type tanker aircraft for support, which has essentially the same airframe and engine as the AMSA penetrator, with different airborne equipment. It would operate on a peacetime basis in a manner similar to the KC-135 with the same crew ratio, deployment, flying hour program, etc.

System 2 has the modified KC-135 tanker for support. This tanker is the current KC-135A modified for short takeoff, with a jet takeoff assist kit. We assume that these aircraft could be made available upon phase-out of the B-52 fleet. These aircraft would also operate in a manner similar to that of the current KC-135.

Systems 3 through 9 use submersible tankers for support. The characteristics of these tankers are as follows:

1.	Length	89 ft
2.	Wing span	77 ft
3.	Material	Steel*

*Steel with a yield strength of 50,000 psi, used in submarine construction circa 1942-1958.

4.	Number of engines	4 turbojet
5.	Gross weight	300,000 lb
6.	AMPR weight	88,000 lb
7.	Maximum speed	Mach 0.9
8.	Maximum thrust	120,000 lb
9.	Fuel and payload	182,000 lb
10.	Wing loading	200 lb sq ft

The original concept of a submersible system involved the use of submerged platforms upon which are moored the submersible tanker aircraft, as shown in Fig. 3. The platforms were conceived as having fuel storage capacity and personnel to man them, with living quarters for the platform crews and for the aircraft personnel. An alternative suggestion, however, was to provide refueling capability by means of a hybrid system consisting of strategically located unmanned fuel platforms, to which land-based submersible tanker aircraft could be flown, submerged, refueled, and made ready to refuel their bomber mates when required. System 9 is of this type and has been called a "land-based flyout system."

Equipment Requirements

The general procedure for determining the equipment requirements was a logical progression, as follows:

1. Determine the number of alert penetrators required.
2. Calculate the total penetrators necessary to support the required number on alert.
3. Determine the number of alert tankers necessary to support the alert penetrators.
4. Calculate the total tankers necessary to guarantee the proper number on alert.
5. For the submersible systems, determine how many platforms are necessary to moor the requisite number of alert tankers, as well as to handle rear area requirements.
6. Calculate the total platforms necessary to guarantee the proper number on alert or in use in rear areas.
7. Determine how many pusher submarines each system requires to provide the indicated degree of mobility.

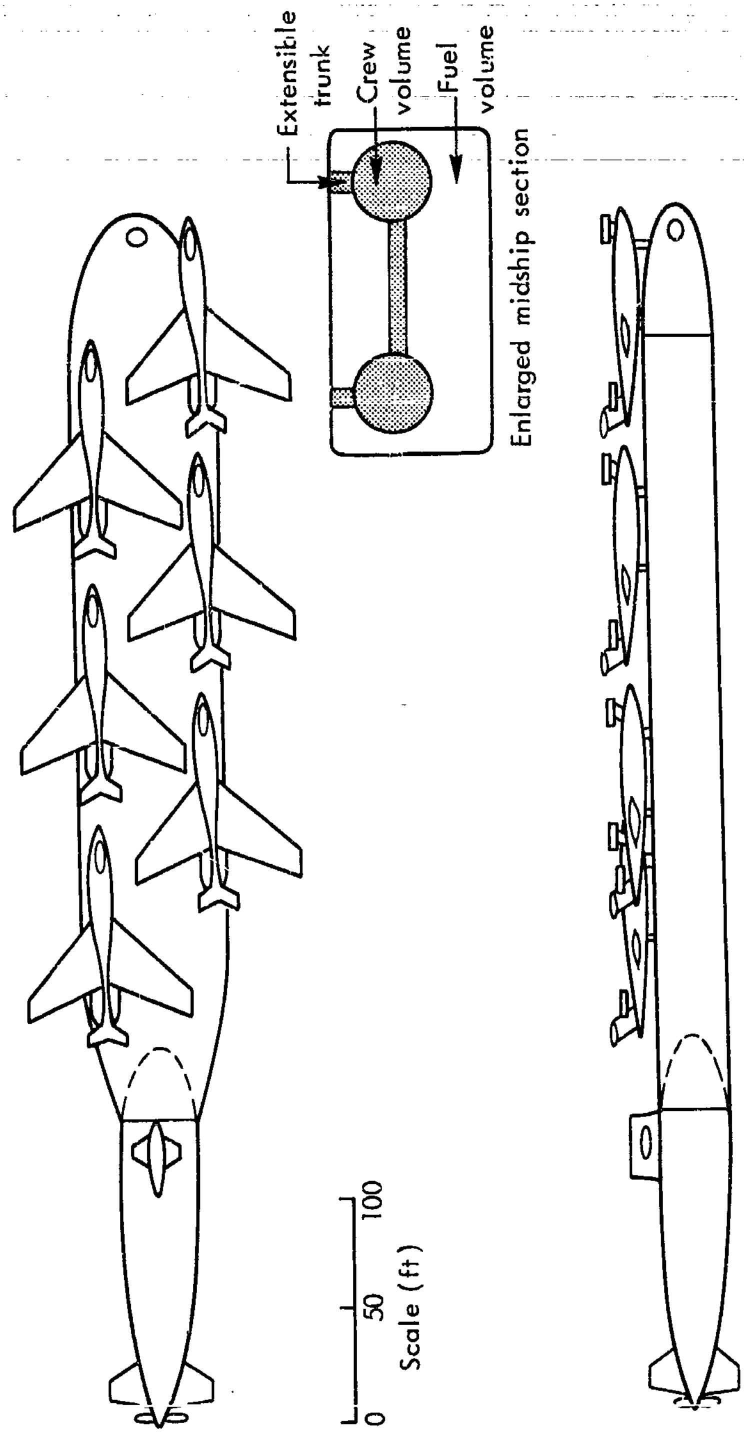


Fig.3—Submersible tanker-aircraft platform with nuclear pusher tug and complement of six aircraft

8. Calculate the total pusher submarines required for each system to guarantee System 7.

9. Determine how many platforms would be required for System 9, the flyout system.

The results of these calculations for each of the nine AMSA systems have been presented in Table 1. However, an illustrative sample calculation for one of the submersibly supported systems (System 4) is presented here according to the steps indicated above.

1. For purposes of comparison, the number of alert penetrators was established arbitrarily at 100.

2. Since the alert requirement was set at 50 per cent ground alert, 200 operational penetrator aircraft would be required. This does not include command support or attrition aircraft.

3. The number of alert tankers necessary (91) was determined through the use of a tanker-to-bomber ratio (0.91). This ratio was calculated by determining the number of tanker aircraft for each refueling made and then employing a weighted average.

4. To allow for unforeseen contingencies in the underwater environment, with which the Air Force has no experience, 20 per cent extra moored tanker aircraft has been allowed. This should provide the necessary 91 in a state of readiness. Per platform this means that of the six moored there, five may be assumed to be ready at all times. Thus, to have the 91 available, 109.2 must be provided for each 100 alert penetrators.

   Assuming that we are discussing here System 4, which is a high mobility system on 50 per cent underwater alert, we can continue with the calculation of the tankers required by estimating the rear area (training, maintenance, etc.) requirement. For 50 per cent underwater alert we would require an equal number of aircraft for backup, or another 109.2. This makes a total of 218 operational tanker aircraft required.

5. In determining the number of platforms required, the assumption was made that rear area tankers are evenly distributed between training and maintenance activities. No platforms would be necessary for tankers in maintenance. Since the platforms are designed to accommodate six tanker aircraft each, the necessary number would be

$$\frac{109.2 + (109 \div 2)}{6}\text{, or } 27.3.$$

6. To the above number of platforms was added an additional 10 per cent to allow for platform maintenance -- total: 30 platforms.

7. For <u>high</u> mobility systems it was decided that each platform on alert should have its own pusher submarine. System 4 would, therefore, require 18.2 operational pusher submarines.
8. For platforms used in training, it was decided to allow one pusher submarine for each two platforms, or 4.5 submarines. Total submarines so far: 22.7. Allowing 10 per cent for necessary pusher submarine maintenance (or 2.27), we arrive at a total of 25 pusher submarines required for System 4.

Had we used System 9, the land-based submersible tanker system, as an example, we would have arbitrarily assumed that 25 platforms would be sufficient. It was also assumed that no pusher submarines would be procured for this system, but that the Navy would be given the responsibility for the one-time requirement for moving the platforms to their posts.

THE PARASITE PENETRATOR AND ITS LONG ENDURANCE AIRCRAFT PLATFORM

The parasite/LEA penetrator systems involve the use of two aircraft to fulfill the stipulated mission. A penetrator with a low level speed and payload similar to the AMSA, but with reduced fuel capacity, is carried toward its target by a Mach 0.3 LEA and released about 1000 miles from the target. After completion of its mission, it is recovered and ferried back to its base in the ZI.*

The technical characteristics of the parasite and LEA are as follows:

		Parasite	LEA
1.	Length	51 ft	180 ft
2.	Wing span	33 ft	390 ft
3.	Material	Aluminum	Aluminum
4.	Number of engines	2 turbofans	4 turbojets and 4 turboprops
5.	Gross weight	55,000 lb	475,000 lb
6.	AMPR weight	16,000 lb	158,000 lb
7.	Maximum speed	Mach 0.9	Mach 0.3

*For a detailed description of this system and its operational concepts, see R. B. Murrow and A. J. Tenzer, <u>Low-altitude Manned Penetrators: A Comparison of Dromedary-carried Parasite and Tanker-supported, Large Bomber Systems</u> (u), The RAND Corporation, RM-3791-PR, January 1965 (Secret).

8.	Maximum thrust/aircraft	13,000 lb	19,000 lb (turbojets), 13,000 H.P. (turboprops
9.	Fuel and payload	32,000 lb	307,000 lb
10.	Wing loading	200 lb/sq ft	38 lb/sq ft
11.	Laminar flow control (wing)	No	Yes
12.	Variable swept wing	No	No
13.	Maximum endurance	N/A	100 hr

In this study two systems using the parasite/LEA have been postulated and examined, differing only in alert configuration. System 10 is one in which the aircraft are on 75 per cent airborne alert System 11 is one in which the aircraft are on 50 per cent ground alert.

For System 10 we assumed that no additional requirement for training flights would exist. Deployment would be 15 aircraft per ZI base, in some combination of parasites and LEA's. With an assumed limit of 120 flying hours per month for aircrew members, the crew ratio of 4.8 was derived. A total crew of 12 was deemed necessary for the combined parasite/LEA aircraft.

For System 11 an operational program similar to the AMSA was assumed--i.e., a flying hour program of 650 hours per aircraft per year and a crew ratio of 2.0. Deployment of 15 aircraft was assumed per ZI base, with a crew complement of 12.

Equipment Requirements

For System 10 the requirement for alert penetrators was again set at 100. Based on the endurance capability of the LEA aircraft, together with maintenance and other operational assumptions, it was found that 134 aircraft would be necessary to maintain 100 aircraft airborne at all times. This amounts to approximately 75 per cent utilization, or 75 per cent airborne alert.

For System 11 the requirement for 100 alert penetrators on 50 per cent ground alert results in a need for 200 each of the parasite and LEA. This does not include aircraft for command support or attrition.

THE SUBMERSIBLE PENETRATOR AIRCRAFT

The third penetrator aircraft examined in this study is the submersible penetrator aircraft. This penetrator is one capable of being submerged in a covert position.

The technical characteristics of the SPA are as follows:

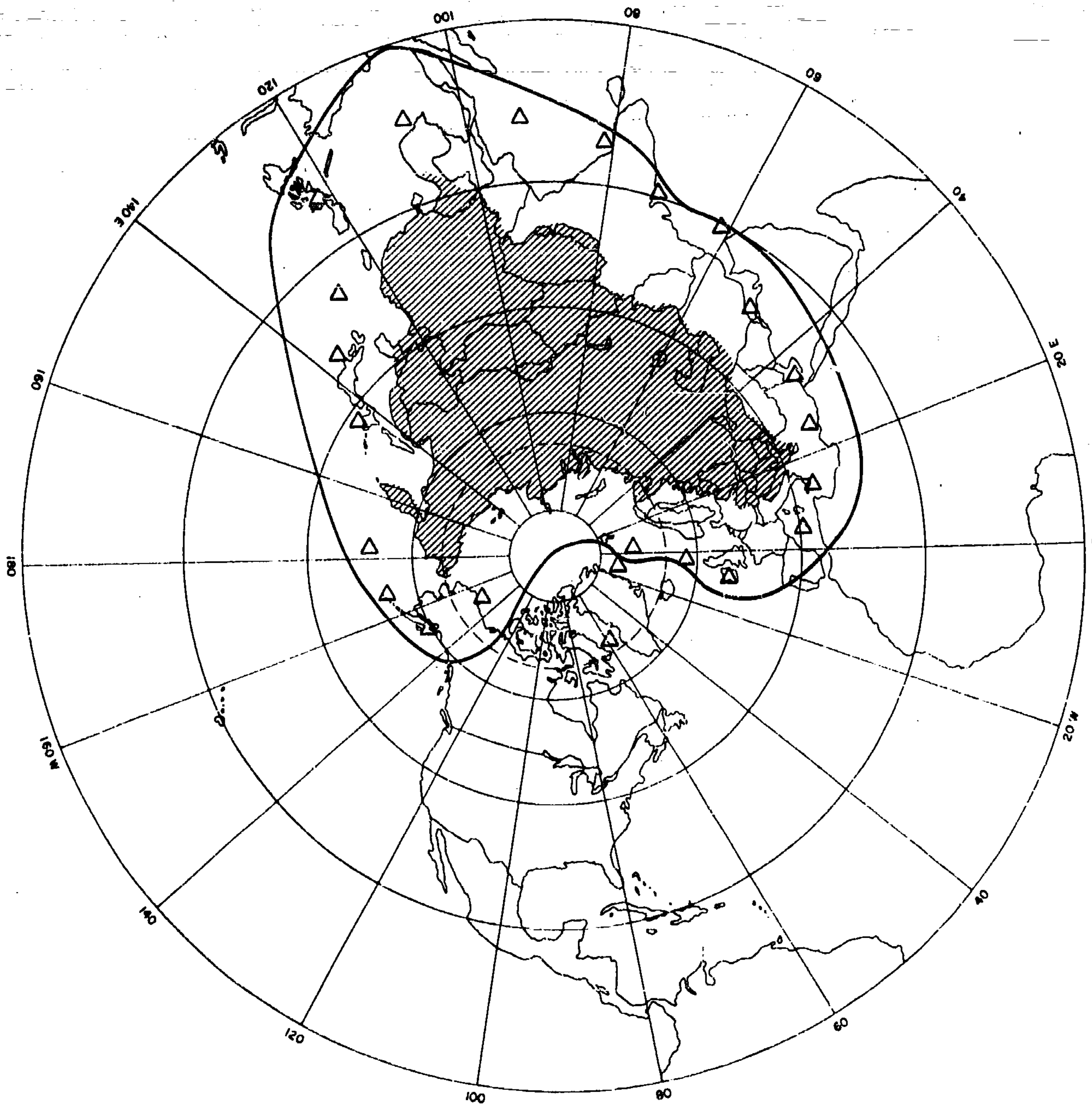
1.	Length	62 ft
2.	Wing span	45 ft
3.	Material	Steel*
4.	Number of engines	3 turbojets
5.	Gross weight	100,000 lb
6.	AMPR weight	25,000 lb
7.	Maximum speed	Mach 0.9
8.	Maximum thrust per aircraft	40,000 lb
9.	Fuel and payload	60,000 lb
10.	Wing loading	200 lb/sq ft
11.	Variable swept wing	No
12.	Laminar flow (wing)	No

The SPA aircraft would be based around the periphery of the Sino-Soviet land mass at a distance of about 1000 miles, as shown in Fig. 4. Like the previously discussed penetrator systems, it would become operational in the mid-1970's, replacing the B-52, on a one-for-one basis. It would be similar to the B-52 in manning, maintenance, and peacetime flying hour program. It would be moored on submerged platforms as shown in Fig. 5, or, in the case of System 18, it would be based in the ZI with a capability for flying out to an unmanned submerged fuel platform and submerging for refueling purposes.

Seven weapon systems have been examined using the SPA aircraft. Six of these have submerged basing and fueling support, and the seventh is the flyout system. The SPA systems are as follows (with high and low mobility and the underwater alert fraction as previously discussed for the AMSA systems):

---

*Steel with a yield strength of 50,000 psi, used in submarine construction circa 1942-58.



Δ Submerged-basing locations

Fig. 4—Sino-Soviet-bloc target system with contour ~ 1000 n mi from target perimeter

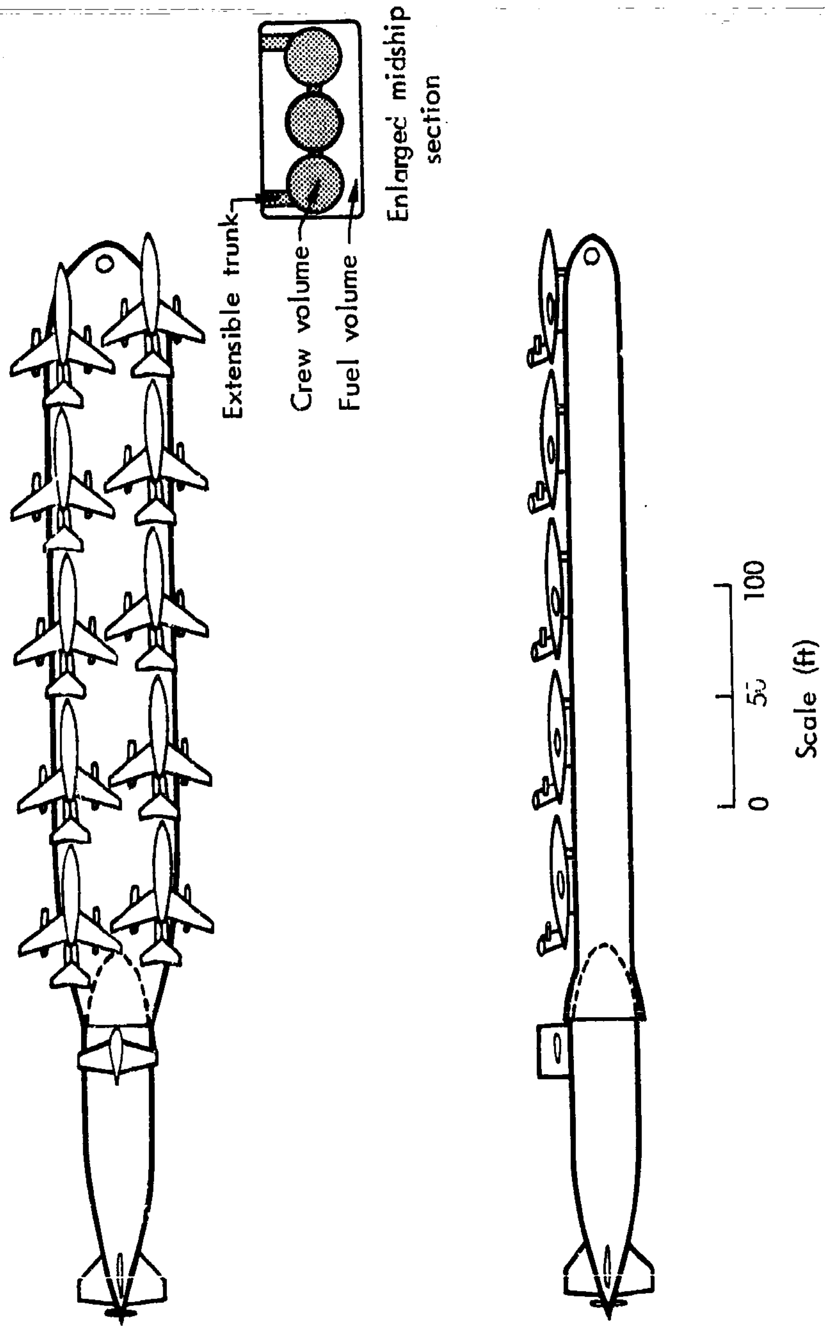


Fig. 5—Submersible penetrator aircraft platform with nuclear pusher tug and complement of ten aircraft

12. SPA penetrator, underwater based, high mobility, 33-1/3 underwater alert.

13. SPA penetrator, underwater based, high mobility, 50 per cent underwater alert.

14. SPA penetrator, underwater based, high mobility, 66-2/3 per cent underwater alert.

15. SPA penetrator, underwater based, low mobility, 33-1/3 per cent underwater alert.

16. SPA penetrator, underwater based, low mobility, 50 per cent underwater alert.

17. SPA penetrator, underwater based, low mobility, 66-2/3 per cent underwater alert.

18. SPA penetrator, land based, on 50 per cent ground alert, with flyout to unmanned submerged platform.

For Systems 12 through 17 the submersible platforms are essentially the same as those used with the submersible tankers for the AMSA system. Ten penetrators are moored upon each platform. Using the same rationale as for the submerged tankers, it was presumed that of the ten SPA's on station, eight would be in a state of readiness.

Equipment Requirements

The general procedure for determining the equipment requirements was as follows:

1. Determine the number of alert penetrators required.
2. Calculate the total penetrators necessary to guarantee the required number on alert.
3. Calculate the number of platforms necessary to moor the requisite number of alert penetrators, or necessary for rear area requirements (training, etc.).
4. Calculate the total platforms necessary to guarantee the number required in Step 3.
5. Determine how many pusher submarines each system requires to provide the indicated degree of mobility.
6. Calculate the total pusher submarines required for each system to provide the indicated degree of mobility.
7. Determine how many fueling platforms are required for System 18, the flyout system.

The results of these calculations have been presented in Table 1. An illustrative calculation follows, given according to the steps indicated above. Since the example used for the AMSA with submersible tanker support had high mobility and a 50 per cent underwater alert fraction, we shall now use for illustration a low mobility system with a 33-1/3 per cent underwater alert fraction (System 15).

1. The number of alert penetrators was again set at 100.
2. Having arbitrarily assumed that only eight of the ten SPA's on each platform will be in a state of readiness at any given time, it will be necessary to have 125 SPA's on station to guarantee 100 in readiness. Since this system is one with a 33-1/3 per cent sea alert, we arrive at a requirement for three times 125 operational aircraft, or 375.
3. In determining the number of platforms required, the assumption was again made that rear area aircraft would be evenly distributed between training and maintenance activities and that no platforms would be required for aircraft in maintenance. With each platform designed to accommodate ten aircraft, the total number necessary would be

$$\frac{125 + (250 \div 2)}{10}, \text{ or } 25.$$

4. To the 25 platforms would be added an additional 10 per cent (or 2.5) to allow for platform maintenance -- total: 28 platforms.
5. For a <u>low</u> mobility system, such as System 15, the assumption was made that there would be one pusher submarine for each of six geographic locations.
6. Fifty per cent (or three) additional submarines for reliability and maintenance; total: nine pusher submarines.

For System 18 we again assumed a requirement for 25 platforms only, and for no pusher submarines.

PERSONNEL REQUIREMENTS

A significant portion of the costs included in such analyses are directly related to the personnel requirements. Pay and allowances, training of replacements, travel expenses, cost of organizational equipment, and many similar costs vary directly with personnel strength. For this reason a reliable estimate of personnel requirements is a crucial part of a weapon/support system cost analysis.

Generally speaking, there are four major types of personnel required for tactical systems:

. Operational
. Maintenance
. Administrative
. Support

Operations personnel are concerned most directly with the operation of the primary equipment (e.g., the flight crews that man the aircraft). Maintenance personnel keep the primary mission equipment functioning effectively.

These two categories of personnel are supported by others, the administrative and support personnel. Personnel record keeping, command, pay administration, food services, recreation, housing, off-duty education -- all these services are provided to personnel at military installations; and someone must perform these services. The functions of such personnel are not directly related to the primary equipment of the weapon system, but rather to the personnel of the weapon system. Since an increase in the number of directly related operational and maintenance personnel of a weapon/support system will result in some increase in the requirement for administration and support, these types of personnel may also be considered as part of the resources required by a weapon/support system.

Within the organizational framework of the Air Force it is relatively easy to determine the relationship between individual weapon/support systems and their operational and maintenance personnel. For operational personnel, information is required about such things as the amount of primary equipment (e.g., aircraft), the mission requirements (e.g., hours to be flown), the number of personnel required per aircraft, the allowable crew flying hours, and other such categories of information.

To relate maintenance personnel to weapon/support systems is less easy, but is usually accomplished using some measure of the workload, which in turn depends on the physical characteristics of the equipment, its reliability, and the applicable maintenance philosophy.

In the case of administrative and support personnel the problem of identification is more difficult. Generally speaking, however, estimating relationships can be, and have been, derived for determining the number of administrative and support personnel likely to be required, based on operational and maintenance personnel strength.*

Host Systems Versus Tenant Systems

To arrive at an estimate of the personnel requirements for the eighteen penetrator systems in this study, it was necessary to make some assumptions regarding the methods of basing the aircraft. What is referred to here is the determination of the host/tenant status of the systems at the bases from which they would operate, or which would be considered their home stations when not on airborne or underwater alert. This is important because a host system has responsibility for exercising the base command function, and within our methodology, it has ascribed to it the number of people who would be necessary to operate the base if there were no tactical units assigned to the base. The tenant systems are charged with those additional support personnel who are required due to the addition of the tactical units to the base.** Since in our study the penetrator systems are considered to be replacements for the B-52, which is usually a host system, we have assumed that the penetrator aircraft would take on the same host organizational responsibility as the B-52. Conversely, all support aircraft (tankers, both submersible and other, and the LEA platform) would be located as tenants on bases of the Strategic Air Command.

Personnel necessary for the FLAM*** air-to-ground missiles have been included in the estimated personnel requirements for the aircraft. It must be noted, however, that no personnel requirements have been estimated to provide for manning of the submersible support equipment

*J. P. Large (ed.), Concepts and Procedures of Cost Analysis, The RAND Corporation, RM-3589-PR, June 1963, Chap. XII, p. 9.

**A. J. Tenzer, O. Hansen, and E. M. Roque, Relationships for Estimating USAF Administrative and Support Manpower Requirements, The RAND Corporation, RM-4366-PR, November 1964.

***Forward launched aerodynamic missile.

(platforms or pusher submarines). As noted previously, no operational or support details for such equipment was provided, nor could they be projected from current USAF operations. In consequence, no attempt was made to derive personnel estimates for the undersea equipment operation and support, but rather a provision was made for personnel costs within the operating cost factor used.

The Personnel Estimates

The requirement for operations personnel, who in our study would be the personnel in the bomber and/or air refueling squadrons, was calculated by multiplying the number of personnel in each crew (which is a consequence of the aircraft design and mission) by the crew ratio (which is determined by the maximum permissible flying time for each crew). To the result is then added an additional 10 per cent to allow for squadron nonflying personnel. The crew ratio for all systems, except the parasite/LEA on airborne alert, was assumed to be 2.0 (two crews per aircraft). This is somewhat higher then the crew ratio currently used for the B-52/KC-135. For the parasite/LEA on airborne alert the crew was assumed to fly 120 hours per month, which results in a crew ratio of 4.8.

Maintenance personnel, for our purposes, would be the personnel of Organizational Maintenance, Field Maintenance, Munitions Maintenance, Missile Maintenance, and Armament and Electronics squadrons. Such personnel have been estimated by an approach used in the Manned Bomber study,* which, generally speaking, assumes a constant minimum number (50) of maintenance personnel per base, augmented by an increment dependent on the aircraft weight and engine thrust of the weapon systems on the base. For penetrator aircraft (with their more complex avionics), an additional 100 personnel per 15 aircraft were allowed. Where the system includes submersible aircraft, the personnel estimate was increased by another 20 per cent, of which half would provide

*Cost Analysis Department, Weapon Systems Cost Estimates of the Penetrating Manned Bomber Study (U), The RAND Corporation, RM-3073-PR, April 1963 (Secret--Privileged Information).

maintenance on the platforms and the other half would satisfy additional base maintenance requirements, the nature of which is as yet unknown.

Administrative personnel are found in the Wing Headquarters units. Support personnel in units such as air base groups, base operationa squadrons, food service squadrons, combat defense squadrons, USAF hospitals, or system requirements for such personnel, are based on the number and type of bases required, and the number of operations and maintenance personnel stationed at those bases, using relationships previously developed.*

A summary of personnel requirements per squadron of 15 aircraft is shown in Table 3.

---

*A. J. Tenzer, O. Hansen, and E. M. Roque, Relationships for Estimating USAF Administrative and Support Manpower Requirements, The RAND Corporation, RM-4366-PR, November 1964.

Table 3

PERSONNEL REQUIREMENTS

Aircraft Type	Basing Host-Tenant	Number in Aircrew	Crew Ratio	Requirements per 15 U.E. Aircraft: Operations Personnel	Maintenance Personnel	Administrative Personnel	Support Personnel	Total Personnel
SPA	Host	2	2.0	66	600	286	1595	2547
AMSA	Host	4	2.0	132	825	313	1682	2952
Parasite	Host	2	2.0	66	495	190	1310	2061
LEA ground alert	Tenant	12	2.0	396	340	118	264	1118
LEA airborne alert	Tenant	12	4.8	946	510	164	502	2122
KC-135	Tenant	6	2.0	198	270	60	184	712
KC-AMSA	Tenant	6	2.0	198	330	68	207	803
Submersible Tanker	Tenant	6	2.0	198	345	70	213	826

III. COST METHODOLOGY

Individual weapon system cost analysis, as distinct from force structure analysis, deals ordinarily with the cost of introducing a new system into the inventory and operating it for an arbitrary period of time, with no reference to cost impact for any specific year. The emphasis is on comparative costs of weapons system that can perform similar wartime missions.

This study has used such an individual cost analysis concept for comparing weapon system alternatives.

TOTAL WEAPON SYSTEM COSTS

A weapon system consists of equipment, personnel, facilities, and skills and techniques, the composite of which forms an instrument of combat in its intended environment. It is usually identified by the name of the major aerospace vehicle associated with it -- B-52, Minuteman, etc. The summation of the costs of all these activities is known as the total weapon system cost.

Obviously, the introduction of a new weapon system into the inventory will not result in a need for completely new land for bases, or for the recruitment of a completely new cadre of personnel, or for all new facilities. Some of these resources will be currently available at any given time, as other weapon systems are phased out, or from within the inventory of existing resources. Existing bases may be expanded, personnel may be retrained, and common equipment may be usable for more than one weapon system. The underlying philosophy of our method is to estimate the incremental cost of introducing the new capability into the inventory.*

MAJOR COST CATEGORIES

There are three major cost categories relating to the key decisions that must be made in the evolution of a weapon system:

---

*For a detailed explanation, see J. P. Large (ed.), Concepts and Procedures of Cost Analysis, The RAND Corporation, RM-3589-PR, June 1963.

to develop it, to buy it after development, and to subsequently operate it. These three major cost categories are Research, Development, Test and Evaluation (RDT&E), Initial Investment, and Annual Operating.

RDT&E includes the design, production tooling, testing, and evaluation of the system. Such RDT&E costs are a function of the extent to which the state of the art must be pushed.

Initial Investment refers to the cost of buying a specified level of capability and introducing it into the force. It includes procurement costs, minor modification costs, and certain personnel costs, such as initial training.

Annual Operating costs, as the name implies, are yearly recurring costs related to the continuance of the capability within the force. These costs, like Initial Investment cost, depend directly on the size of the force.

FIVE-YEAR SYSTEM COSTS

In this study we have compared the cost of alternative strategic weapon systems capable of performing the same mission, that of penetrating the Sino-Soviet land mass and delivering a payload of 10,000 lb of air-to-surface missiles.

These weapon systems consist of at least two of three types of equipment:

1. Aircraft of one or more types
2. Missiles
3. Submersible equipment

The procedure followed in deriving the cost estimates for each of the alternative systems was to first estimate the five-year system cost of the aircraft involved; then the five-year system cost of the missiles; and, finally, where applicable, the five-year system cost of the submersible equipment. For each alternative the appropriate five-year system costs were added together into a total weapon system cost.

The aircraft-related portion of the total system cost ranges from at least 75 per cent to over 95 per cent of the cost of each of the alternative systems under consideration. As a result, we have concentrated our efforts on the estimate of aircraft costs.

Estimates of the costs of developing and procuring a new aircraft are based in large measure on the technical characteristics specified. Since both the RDT&E and procurement cost estimates for this study were prepared concurrently, they will be presented together. The technical characteristics used in making these estimates have already been presented in Section II.

IV. AIRCRAFT COSTS

RDT&E

RDT&E costs in this study were estimated assuming a full weapon system program, in which the selected contractor designs, develops, and builds with production tooling the necessary aircraft to carry the program through Categories I and II testing and the procurement phase. It was assumed that aircraft contractors, and not shipyards, would build the submersible aircraft. The quantity of vehicles selected for the development program was based on the relative complexity of the system involved. This figure varied from five to 30. The test vehicles were not considered as part of the procured inventory.

This approach, in contrast to the prototype approach, permits the use of similar line elements of cost for both the RDT&E and Primary Mission procurement items. A summary of RDT&E costs is shown in Table 4.

PRIMARY MISSION EQUIPMENT

Use of the weapon system program approach permits the breakdown of production costs to be extensions of the RDT&E cost elements. The RDT&E program includes the cost of testing for a given quantity of vehicles in quantity after RDT&E is completed. Table 5 provides a summary of procurement costs, and Figs. 6 and 7 show the cumulative average cost-quantity curve excluding and including RDT&E

Engineering

In this study, engineering cost includes the cost of the line and staff engineering personnel, both direct and indirect, that would be required for the design and system integration of the complete vehicle. It also includes the cost of engineering and manufacturing personnel required to provide the necessary development and component testing (e.g., wind tunnel, materials laboratory, etc.) during the initial

Table 4

SUMMARY OF RDT&E COSTS

($ million)

	AMSA Bomber	AMSA Tanker[a]	AMSA Tanker[b]	KC-135 Tanker	Submersible Tanker	Long Endurance Aircraft	Parasite Aircraft	Submersible Penetrator
Number of test vehicles	20	5	5	0	30	15	20	30
Engineering	360	57	53	0	750	165	51	390
Tooling	200	29	27	0	163	256	27	54
Avionics	150	0	0	0	10	10	150	150
Engines	600	0	0	0	100	40	20	50
Flight test vehicles	437	57	30	0	324	190	148	241
Flight test operations	200	17	17	0	453	33	36	422
Contingency	0	0	0	0	360	0	0	261
Total	1,947	160	127	0	2,160	694	432	1,568

[a] After production of 100 AMSA bombers.

[b] After production of 1000 AMSA bombers.

Table 5

SUMMARY OF PRIMARY MISSION EQUIPMENT PROCUREMENT COST (CUMULATIVE AVERAGE)
($ million)

	Cumulative Quantity[a]			
Number of vehicles	100	200	400	1000
AMSA bomber	13.965	12.136	10.404	8.369
AMSA tanker[b]	9.467	8.417	7.309	5.947
AMSA tanker[c]	5.698	5.620	5.429	5.113
KC-135 tanker	0.500	0.390	0.300	0.215
Submersible tanker	12.364	10.664	9.162	7.358
Long endurance aircraft	7.681	6.400	5.637	4.467
Parasite aircraft	4.620	4.221	3.841	3.332
Submersible penetrator	8.632	7.640	6.734	5.552

[a]Subsequent to RDT&E test vehicles.

[b]After production of 100 AMSA bombers.

[c]After production of 1000 AMSA bombers.

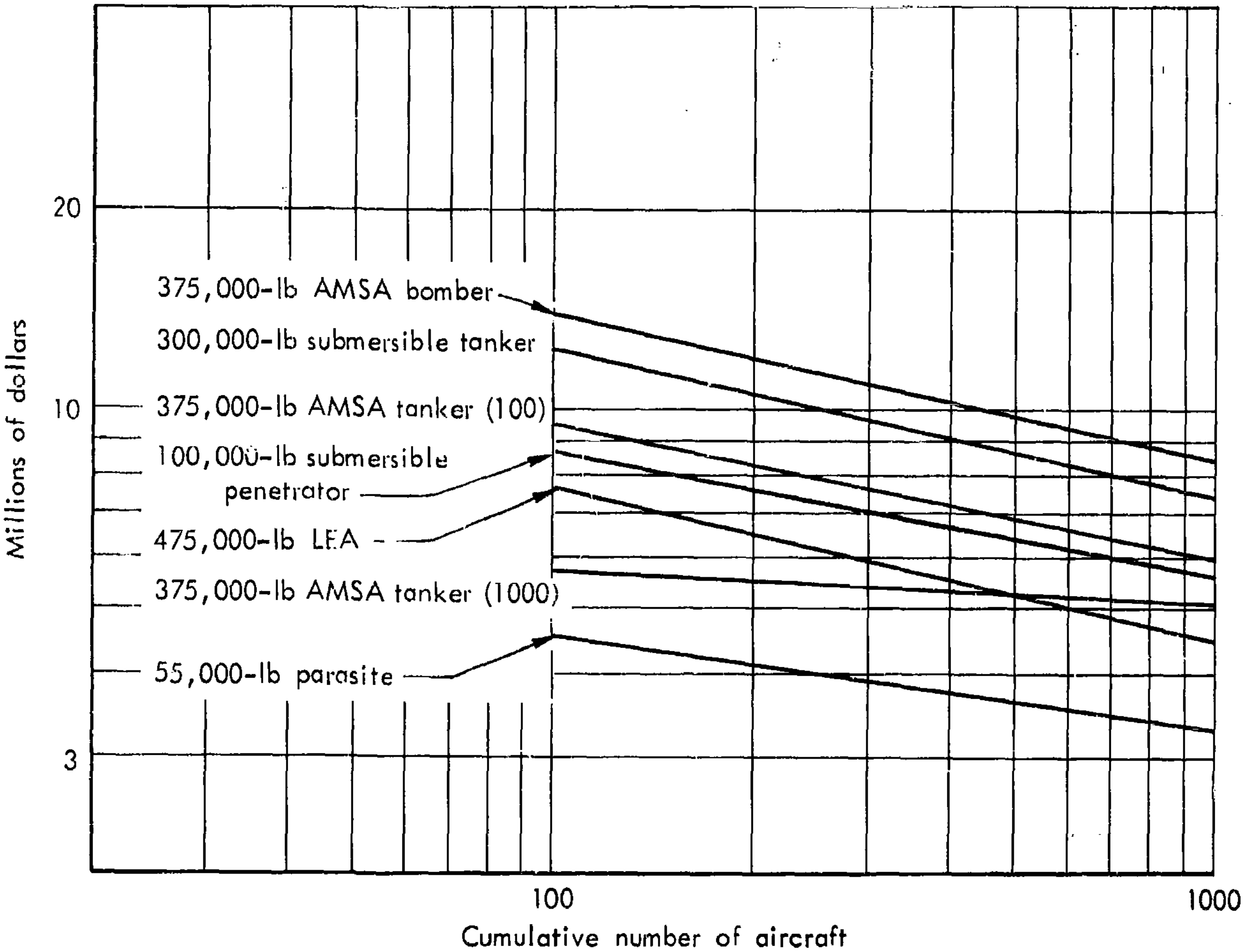


Fig.6—Cumulative average cost curve excluding RDT&E

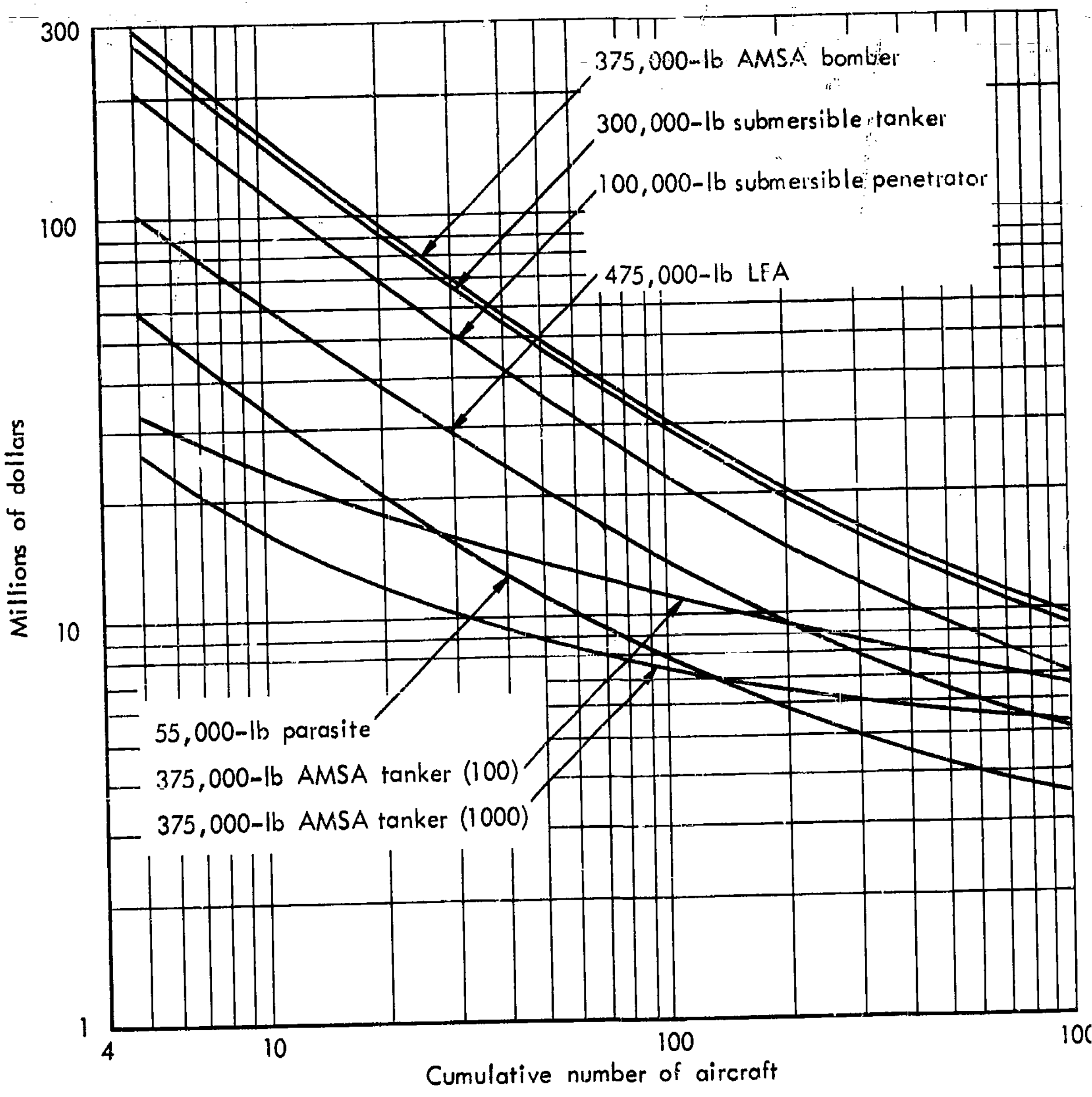


Fig. 7—Cumulative average cost curve including RDT & E

mockup and subsequent qualification-testing phases, as well as the necessary materials. The cost of engineering shown in Table 3, for example, is carried to the point of completion of the required number of test vehicles. Not included is the engineering and manufacturing manpower required for the flight test program.

The engineering cost estimates shown are based on historical information on conventional military aircraft, formalized statistically into the following expression:

$$\text{Log } T_1 = 0.90462 + 0.54716 \text{ log knots} + 0.88000 \text{ log thrust},$$

where T_1 = the engineering hours for the first unit.

The total engineering effort up to any given cumulative aircraft quantity is estimated from this expression:

$$\text{Total engineering hours} = T_1 N^{0.2},$$

where T_1 is derived as above, and N = cumulative quantity produced.

It was recognized that certain of the aircraft have characteristics quite different from those on which the foregoing relationship was based. Because of this, an adjustment was made for the AMSA bomber, for example, to compensate for the presence of a variable sweep wing. Also, considerable adjustments were made to the estimate of engineering hours for the submersible aircraft to account for the following items:

(1) Coordination with the shipbuilding industry on marine technology for the submerged mode.

(2) Development of a new confidence base, from the structural viewpoint, to account for the new loading spectrum and the use of steel as the primary structural material.

(3) Additional development testing for the underwater subsystems, water-ski landing gear, jet flap, and flooding of fuel cells (behind bladders) and engine intakes for water ballast provisions.

(4) Loss of efficiency due to coordination problems in areas described above that would result in more than the normal level of false starts during the early design stages.

Adjustments were also made in the case of the LEA to allow for the introduction of laminar flow control techniques.

Tooling

Tooling represents the summation of initial tooling, duplication for tool production rate increases and sustaining tooling costs. Included are tool design, planning, tool inspection, and tool materials. The formal estimating relationship used for this is as follows:

$$\text{Log } T_1 = 2.79589 + 0.66637 \log \text{knots} + 0.46715 \log \left(\text{gross wt} \times \frac{\text{thrust}}{10^6}\right),$$

where T_1 = initial tooling hours

Total tooling hours = $T_1 F_n N^{0.138}$,

where T_1 is as above,

$F_n = R_n^{0.40}$ = adjustment factor for production rate tooling,

N = cumulative quantity produced.

As in the case of engineering, adjustments were made wherever necessary to allow for the increased complexity of the AMSA pivot wing or the laminar flow control on the LEA, or for the reduced complexity to tool for steel on the submersible aircraft. These adjustments were made by taking into account the details of the individual designs.

Avionics

The costs shown in RDT&E for avionics are those incurred by the avionics industry to develop the necessary avionic equipment for the mission requirements. Two values are shown: $150,000,000 for aircraft that penetrate the enemy's defenses (AMSA, submersible penetrator, and the parasite aircraft), and $10,000,000 for the aircraft support (tankers and LEA). These values were based on individual estimates that have yet to be formally documented. Costs for installed avionic equipment are included in the "Flight test vehicle" line item (for RDT&E) and under "Avionics" (for production).

Engines

New engines were considered for one airplane, the AMSA bomber. Estimates for RDT&E were based on historical data derived from engine contractors. The values include the full cost for component development and testing, engine demonstrators, qualification through Preliminary Flight Rating Test and Model Qualification Test, together with a proportion of product improvement cost depending on the quantity produced. The relationship used as a base to describe the RDT&E costs for a turbojet engine is:

$$\text{Log } Y_{j2000} = -0.32480 + 0.67471 \log T,$$

where Y_{j2000} = total development cost for a turbojet engine to the 2000th production delivery in millions of dollars (not included is the production cost of 2000 engines),

T = turbojet thrust, including afterburner (lb).

Existing engines were assumed for the remaining aircraft under consideration; the RDT&E cost shown in Tables 6 through 12 is for modifications for the particular application.

Individual engine costs, which are based on historical data versus quantity produced, are included either in the "Flight test vehicles" (for RDT&E), or under "Engines" (for the production program).

Production

Production labor estimates, including quality control, were based on the individual characteristics of the vehicle in relation to the historical raw data existing on previous aircraft. Although certain formal relationships are available that condense this raw data into statistical regression equations, it was considered inappropriate to use parameters involving weight, for example, on airplanes using steel for primary structure. Because of this, the production costs for all aircraft considered were established and compared with one another on the basis of available raw data on similar forms of construction and with the use of considerable collective judgment. To allow for the cost impact of the use of steel for the structure, the submersible aircraft were first considered as having all aluminum construction with an AMPR weight to gross weight ratio similar to other similarly sized aircraft. Then the production hours normally attributed to this weight of structure were subdivided into structure and subsystems, and an adjustment was made to the structure portion to allow for the use of steel, the subsystems portion remaining constant. Production hours for the AMSA and LEA aircraft included adjustments for variable wing sweep and laminar flow control, respectively. The effect of disruptions normally associated with the production of advanced systems was included in the submersible aircraft production costs by adjustments to the slope of the cost-quantity curve.

In all cases the cost of the first series of airplanes was assigned to the "Flight test vehicles" line item in Tables 6 through 13, under RDT&E; the cost of the remainder was assigned to production.

Material

Costs of material for the aluminum airplanes were based on historical values as a function of weight and type of materials employed. For the steel airplanes, modifications to these values were made, based on raw material cost differences.

Flight Test Operations

Except for the submersible cases, all aircraft flight test costs are for Category I tests only. Since the submersible aircraft will undergo considerably more Category II testing than conventional aircraft, an allowance has been included for this difference. The incremental value of $200 million shown in Tables 8 and 12 is quite arbitrary and has little justification except for the opinion that some allowance should be made to cover testing in a combined marine/aeronautical environment for which the Air Force is not presently equipped.

Table 6

AMSA BOMBER
($ million)

Gross weight....... 375,000 lb
Maximum Mach no.... 2.5
Material.......... Aluminum

Research, Development, Test & Evaluation--Total Costs	
Engineering.................	360
Tooling.....................	200
Subsystems..................	150
Engines.....................	600
Flight test vehicles (20)....	437
Flight test operations.......	200
Total..................	1947

Production--cumulative average cost Less RDT&E	Production Airplane Quantity			
	100	200	400	1000
Engineering	1.440	1.060	0.717	0.405
Tooling	0.585	0.397	0.266	0.144
Production	5.117	4.338	3.587	2.644
Material	1.290	1.179	1.089	0.965
Avionics	3.308	3.112	2.895	2.561
Engines	2.225	2.050	1.850	1.650
Total	13.965	12.136	10.404	8.369

Table 7

55,000-lb PARASITE
($ million)

Gross weight........ 55,000 lb
Maximum Mach no..... 0.9
Material........... Aluminum

Research, Development, Test & Evaluation--Total Costs	
Engineering................	51
Tooling....................	27
Subsystems.................	150
Engines....................	20
Flight test vehicles (20)...	148
Flight test operations......	36
Total..................	432

Production--cumulative average cost Less RDT&E	Production Airplane Quantity			
	100	200	400	1000
Engineering	0.210	0.147	0.103	0.059
Tooling	0.060	0.033	0.022	0.013
Production	0.657	0.558	0.461	0.354
Material	0.159	0.145	0.134	0.119
Avionics	3.308	3.112	2.895	2.561
Engines	0.226	0.226	0.226	0.226
Total	4.620	4.221	3.841	3.332

Table 8

SUBMERSIBLE PENETRATOR
($ million)

Gross weight........ 100,000 lb
Maximum Mach no..... 0.9
Material........... Annealed steel

Research, Development, Test & Evaluation--Total Costs	
Engineering...............	390
Tooling..................	54
Subsystems...............	150
Engine...................	50
Flight test vehicles (30)..	241
Flight test operations.....	422[a]
Contingency--20 per cent...	261
Total................	1568

Production--cumulative average cost Less RDT&E	Production Airplane Quantity			
	100	200	400	1000
Engineering	1.560	1.155	0.830	0.475
Tooling	0.217	0.153	0.107	0.060
Production	1.265	1.117	0.965	0.739
Material	0.216	0.203	0.188	0.165
Avionics	3.308	3.112	2.895	2.561
Engines	0.627	0.627	0.627	0.627
Contingency--20 per cent	1.439	1.273	1.222	0.925
Total	8.632	7.640	6.734	5.552

[a]Including 200 increment for Category II marine environment testing.

Table 9

KC-135 TANKER MODIFIED
($ million)

Gross weight..........	301,000
Maximum Mach no.......	0.9
Material..............	Aluminum

Research, Development, Test & Evaluation--Total Costs	
Engineering................	0
Tooling....................	0
Subsystems.................	0
Engines....................	0
Flight test vehicles (20)..	0
Flight test operations.....	0
Total.................	0

Modification--cumulative average cost Less RDT&E	Modification Airplane Quantity			
	100	200	400	1000
Engineering	---	---	---	---
Tooling	---	---	---	---
Production	---	---	---	---
Material	---	---	---	---
Avionics	---	---	---	---
Engines	---	---	---	---
Total[a]	0.500	0.390	0.300	0.215

[a]No breakdown into cost elements was made.

Table 10

AMSA TANKER (AFTER RDT&E AND PRODUCTION OF 100 AMSA BOMBERS)
($ million)

Gross weight........ 375,000 lb
Maximum Mach no..... 2.5
Material............ Aluminum

Research, Development, Test & Evaluation--Total Costs	
Engineering................	57
Tooling....................	29
Subsystems.................	0
Engines....................	0
Flight test vehicles (5)....	57
Flight test operations......	17
Total...............	160

Production--cumulative average cost Less RDT&E	Production Airplane Quantity			
	100	200	400	1000
Engineering	0.687	0.457	0.302	0.226
Tooling	0.497	0.429	0.281	0.150
Production	4.326	3.839	3.281	2.486
Material	1.290	1.179	1.089	0.965
Avionics	0.555	0.533	0.508	0.470
Engines	2.112	1.980	1.848	1.650
Total	9.467	8.417	7.309	5.947

Table 11

AMSA TANKER (AFTER RDT&E AND PRODUCTION OF 1000 AMSA BOMBERS)
($ million)

Gross weight........ 375,000 lb
Maximum Mach no..... 2.5
Material........... Aluminum

Research, Development, Test & Evaluation--Total Costs	
Engineering..................	53
Tooling......................	27
Subsystems...................	--
Engines......................	--
Flight test vehicles (5)......	30
Flight test operations........	17
Total.....................	127

Production--cumulative average cost Less RDT&E	Production Airplane Quantity 100	200	400	1000
Engineering	0.174	0.174	0.174	0.174
Tooling	0.151	0.147	0.138	0.122
Production	2.514	2.462	2.305	2.043
Material	0.982	0.982	0.982	0.982
Avionics	0.555	0.533	0.508	0.470
Engines	1.322	1.322	1.322	1.322
Total	5.698	5.620	5.429	5.113

Table 12

SUBMERSIBLE TANKER
($ million)

Gross weight......... 300,000 lb
Maximum Mach no...... 0.9
Material............. Annealed steel

Research, Development, Test & Evaluation--Total Costs	
Engineering................	750
Tooling....................	163
Subsystems.................	10
Engines....................	100
Flight test vehicles (30)...	324
Flight test operations......	453[a]
Contingency--20 per cent....	360
Total..................	2160

Production--cumulative average cost Less RDT&E	Production Airplane Quantity			
	100	200	400	1000
Engineering	2.900	2.165	1.476	0.847
Tooling	0.627	0.438	0.309	0.176
Production	3.659	3.192	2.785	2.145
Material	0.637	0.634	0.632	0.569
Avionics	0.555	0.553	0.508	0.470
Engines	1.925	1.925	1.925	1.925
Contingency--20 per cent	2.061	1.777	1.527	1.226
Total	12.364	10.664	9.162	7.358

[a]Including 200 increment for Category II marine environment testing.

Table 13

475,000-1b LONG ENDURANCE AIRCRAFT
($ million)

Gross weight......... 475,000 lb
Maximum Mach no...... 0.3
Material............. Aluminum

Research, Development, Test & Evaluation--Total Costs	
Engineering..................	165
Tooling......................	256
Subsystems...................	10
Engines......................	40
Flight test vehicles (15).....	190
Flight test operations........	33
Total.......................	694

Production--cumulative average cost Less RDT&E	Production Airplane Quantity			
	100	200	400	1000
Engineering	0.823	0.412	0.386	0.221
Tooling	0.441	0.295	0.260	0.107
Production	3.747	3.187	2.621	1.966
Material	1.615	1.473	1.362	1.203
Avionics	0.555	0.533	0.508	0.470
Engines	0.500	0.500	0.500	0.500
Total	7.681	6.400	5.637	4.467

CONTINGENCY

A contingency of 20 per cent of the subtotal costs is included for the submersible aircraft to allow for the uncertain state of the design philosophy. For example, the submersible aircraft are based on available conventional engines and the use of steel of a shipbuilding specification. If later studies indicate a mandatory change to a specialized power plant or more sophisticated material to achieve the stated performance specification, any cost increases will be subtracted from the contingency allowance until it is exhausted.

OTHER INITIAL INVESTMENT

In addition to the cost of buying the primary mission equipment, other one-time outlays are necessary in the introduction of a weapon system into the force. These outlays are treated below.

Primary Mission Equipment Spares

This category of initial investment costs includes stocks of spares and spare parts. The cost is computed by taking a percentage of the investment cost of the item of equipment for which the spares are to be used. The major aircraft, and the spares percentage deemed appropriate, are as follows:

Aircraft	Initial Spares (per cent)
Penetrator	
SPA	25
AMSA	20
Parasite	20
Support	
Submersible tanker	25
KC-AMSA	20
KC-135A	20
LEA	20

It should be noted here that an additional five per cent allowance was added to the spare parts for the submersible aircraft. This represents initial spares located on the submersible barge in addition to spares located at base or depot.

Aerospace Ground Equipment and Initial AGE Spare Parts

This category includes items of support equipment required by the aircraft. It includes special vehicles, maintenance and test equipment, and simulation equipment. Since specific equipment requirements have not been provided, a percentage of the cost of the aircraft was used. Cost of spare parts for this equipment was also estimated based on its initial cost. The percentages applied are as follows:

Aircraft	AGE (per cent of PME)	AGE Initial Spares (per cent of AGE)
Penetrator		
SPA	25	20
AMSA	20	15
Parasite	20	15
Support		
Submersible tanker	25	20
KC-AMSA	20	15
KC-135A	20	15
LEA	20	15

In both the AGE and AGE Initial Spares categories, an additional five per cent was added for the submersible systems, to reflect additional underwater requirements of the platform-based systems.

Facilities

This category includes investment in new bases, or in modification of existing bases, resulting from the introduction of a new capability into the force. Since these aircraft would replace strategic aircraft on a one-for-one basis, we assumed that existing bases would be available and would be used. Minor modification costs of $17 million per base would be required for all new aircraft systems. This includes the cost of modifications to hangars and maintenance shops. We have assumed that no runway or taxiway modifications would be required.

Initial Training

This category covers only the formal training required to bring each man up to the level of skill required for his task with the new system. Included are both the direct costs (pay and allowances of students and instructors) and indirect costs (pro rata share of the cost of operating Air Training Command aircraft and bases).

We assumed that only flying personnel would require initial training. All other military personnel would be inherited, already trained, for the systems being phased out. The numbers of crew personnel and the initial training costs per crew are shown below:

Aircraft	Number of Pilots	Number of Other Crew	Cost per Pilot	Cost per Other Crew Member	Total Cost per Crew
Penetrator					
SPA	2	2	$200,000	$ 50,000	$500,000
AMSA	2	2	150,000	50,000	400,000
Parasite	2		150,000		300,000
Support					
Submersible tanker	2	2	200,000	50,000	500,000
KC-AMSA	2	2	150,000	50,000	400,000
KC-135A	2	2	0	0	0
LEA	4	8	25,000	25,000	300,000

MISCELLANEOUS INVESTMENT

Included here are the costs of initial transportation, initial travel, and initial stock level. They are grouped under Miscellaneous

Investment because all of them together average only about one per cent of the total initial investment cost.

Initial travel includes the cost of transporting personnel to the operating bases. Costs are estimated using cost-per-man factors (officers and airmen). For these systems the costs are small because we assumed the inheritance of existing bases and support organizations and their personnel.

Initial transportation includes costs of transporting equipment and stocks, except aircraft (which are assumed to be transported under their own power). This cost was computed by using a relationship that relates this cost to the number of military personnel to be moved to the base, and the initial cost of the equipment (excluding aircraft) that is to be moved to the base.

Initial stock level includes such items as personnel stocks (clothing, food, ammunition), organizational stocks (pots, pans, typewriters), and FOL (fuel, oils and lubricants). The initial cost is based on an estimate of annual consumption and the pertinent Air Force policy that sets the required stock level in terms of a given number of days. We assumed that the stock level policy would not change when the new systems were brought into the force and, since there is no reason for the consumption rate to change materially, there would be only a small incremental cost.

ANNUAL OPERATING COSTS

Discussed in this section are the costs of operating the systems, which will recur during each year of system operation.

Primary Mission Equipment Maintenance

Included here is the annual cost of materials used at the bases and Logistics Command depots for the maintenance of the aircraft. It also includes the cost of labor, both military and civilian, at the depot. If depot maintenance is performed by a contractor, such cost is then substituted for the AFLC depot maintenance cost.

Such costs are normally estimated as a function of the flying hour program, using two separate relationships, as follows:*

Depot maintenance cost per flying hour

$$Y = 14.526 + 0.0498X_1 + 0.0824X_2,$$

where Y = depot maintenance/flying hour,

X_1 = aircraft cumulative average cost at the 500th unit,

X_2 = combat speed in knots.

Base materials cost/flying hour

$$Y = 31.81 + 0.00584X,$$

where Y = base materials cost per flying hour,

X = aircraft cumulative average cost at the 500th unit.

In applying these relationships for the submerged aircraft, an additional 20 per cent was allowed to cover the additional maintenance required for underwater deployment.

The following list presents the maintenance cost per flying hour factors for each aircraft:

Aircraft	Depot Maintenance Cost/ Flying Hour	Base Maintenance Cost/ Flying Hour	Total Maintenance Cost/ Flying Hour
Penetrator			
SPA	404	77	481
AMSA	643	93	736
Parasite	247	54	301
Support			
Submersible tanker	524	91	615
AMSA	494	75	569
KC-135A	307	61	368
LEA	298	63	361

*These relationships were developed for Weapon Systems Cost Estimates of the Penetrating Manned Bomber Study (U), Cost Analysis Department, The RAND Corporation, RM-3073-PR, April 1963 (Secret--Privileged Information).

FUEL, OILS AND LUBRICANTS--PRIMARY MISSION EQUIPMENT

The annual cost of FOL is estimated as a function of the number of flying hours, and of the fuel consumption per hour, for each aircraft (which in turn is related to the aircraft design and intended operational use). For this study we assumed a sortie length averaging 90 per cent of the maximum endurance of each aircraft (except the LEA), to determine the average fuel consumption per flying hour. The LEA, when in the 50 per cent ground alert mode, was assumed to fly sorties that average about eight hours each; and in the 75 per cent airborne alert mode, the average sortie was 90 hours. The following list presents details of specified combat radius, speed, and fuel consumption per flying hour, for the various aircraft:

Aircraft	Combat Radius (n mi)	Speed (kn)	Fuel Consumption (lb/hr)
Penetrator			
SPA	1,000	532	6,200
AMSA	6,000	1,270	18,000
Parasite	1,000	532	5,820
LEA--airborne alert	24,500	207	1,843
Support			
Submersible tanker	2,000	532	6,600
KC-AMSA	6,000	1,270	11,000
KC-135A	6,000	550	14,000
LEA	24,500	207	7,843

PEACETIME ATTRITION--PRIMARY MISSION EQUIPMENT

The cost of PME replacement due to attrition is based on rates expressed on a per flying hour basis. Peacetime attrition rates vary according to the speed and complexity of the aircraft and the types of sorties flown. Fighter aircraft, flying shorter sorties than bombers, have higher attrition rates. The list below presents the estimated attrition rate for each of the aircraft in this study:

Aircraft	Attrition Rate (per 100,000 flying hours)
Penetrator	
SPA	12
AMSA	8
Parasite	8
Support	
Submersible tanker	12
KC-AMSA	8
KC-135A (modified)	2
LEA	3
LEA when on airborne alert	1.5

The high estimate for both the AMSA (with variable wing geometry) and the SPA reflect the uncertainty concerning the ultimate difficulty of operating them. Since attrition is a function of both flying hours and number of sorties, the attrition rate for the LEA on airborne alert, with its tenfold increase in flying hours over the ground alert case, has been estimated at one-half that of the LEA on ground alert.

Aerospace Ground Equipment Maintenance and Replacement

The cost of maintenance and replacement due to normal operation of the aerospace ground equipment is estimated as a percentage (in this study, 15 per cent) of the value of the equipment.

Facilities Maintenance and Replacement

Included here are costs of materials and contractual services needed to maintain the base facilities associated with the aircraft systems. These are usually estimated as a percentage of the cost of the base, or by using a per man factor. In this study we used the per man factor--$200 for facilities maintenance and $500 for facilities replacement.

Personnel Pay and Allowances

The costs included in this cost element are basic pay for military personnel; allowances for such items as quarters, clothing, hazard pay, and subsistence; and costs for permanent change of station travel, and temporary duty travel. This element also includes civilian pay and all associated payroll costs, such as FICA tax and retirement contributions.

Factors used in this study were as follows:

Rated officer............	$10,809 per year
Nonrated officer.........	8,353 per year
Airman..................	3,567 per year

Personnel Replacement Training

This cost element includes the cost of training personnel to replace others leaving the Air Force. The cost is a function of the number of military personnel for each system, the turnover rates, and the cost of training each category. For this study we applied our current turnover factors to the estimated number of crew and other personnel. (The cost of initial crew training has been described previously.) Replacement training for "other" (noncrew) personnel was estimated based on an average initial training cost of $10,000 per man. Turnover factors are as follows:

Rated officers...........	5 per cent
Nonrated officers........	3 per cent
Crew airman..............	4 per cent
Noncrew airman...........	15 per cent

Miscellaneous Annual Operation

Included here are such costs as annual travel, annual transportation, organizational equipment replacement, and annual services and other costs. We have grouped these costs together because of their relatively minor role in this study.

Annual travel costs represent an allowance for the travel of replacement military personnel and their dependents to and from their duty stations. It is estimated on a per military man basis.

Annual transportation includes the cost of transporting to the base the equipment and supplies to replace those consumed during the year. The cost is estimated by applying a 1-1/2 per cent factor to the cost of the material transported.

Organizational equipment replacement includes the cost of replacing such equipment as pots and pans, typewriters, and many other small items required by each aircraft system. The annual cost of replacing this common organizational equipment is estimated at $165 per man.

Annual services and other costs. The many small operating costs not covered elsewhere, such as miscellaneous contractual services, small arms ammunition replacement, and food and clothing are combined in one cost element. Five hundred dollars per man is estimated as sufficient to cover these costs.

We have presented in some detail the method of estimating each of the cost elements shown in Table 14. It should be noted that for this study we have not included costs associated with unit support aircraft. Logistic aircraft and trainer aircraft were assumed to be inherited from the phased out system and were therefore considered to be cost-free. There would be a small annual cost resulting from the operation of these aircraft, but it was not included because it would be very small (less than $0.5 million per squadron per year) and because it would be the same for each of the systems under study.

A reference summary that lists, by cost element, the estimated cost per 100 operational aircraft for each of the types of aircraft used in the study is presented in Table 14. These costs have been used in estimating the aircraft portion of the system costs presented later in this Memorandum.

Table 14

ESTIMATED INITIAL INVESTMENT AND ANNUAL OPERATING COSTS FOR 100 AIRCRAFT

(millions of 1964 dollars)

	Penetrator Aircraft			Support Aircraft				
	Submersible SPA	AMSA	Parasite 70,000-lb Ground or Airborne Aircraft	Submersible Tanker	KC-AMSA	KC-135A (modified)	LEA 475,000-lb Ground Alert	LEA 475,000-lb Airborne Alert
Initial investment								
PME procurement and spares	1031	1997	647	1416	1188	79	1003	1003
AGE procurement and spares	227	366	119	312	218	15	184	184
Facilities	17	17	17	17	17	--	17	17
Training	161	150	80	117	96	14	122	207
Miscellaneous Investment	16	21	7	9	8	5	18	22
Total	1452	2551	370	1871	1527	113	1344	1433
Annual operating costs								
PME maintenance	31	48	20	29	27	18	24	248
PME FOL	6	18	8	5	8	10	8	22
PME attrition	7	9	3	7	4	1	2	9
AGE maintenance and replacement	21	33	11	28	20	1	17	16
Facilities maintenance and replacement	15	17	4	3	3	3	17	20
Personnel pay and allowances	77	86	60	28	27	25	40	76
Personnel replacement training	27	26	14	18	15	11	21	34
Other operating	20	23	8	8	6	6	22	33
Total	204	260	128	126	110	75	151	458

V. AIRBORNE MISSILE COSTS

Within this study each alternative penetrator system under consideration was equipped with air-to-surface missiles. The type and size of each payload was identical for all systems -- eight forward launched aerodynamic missiles per penetrator, rocket powered, and equipped with an all-inertial guidance system. Each would weigh about 1000 lb and carry a 240-lb warhead. The missile is identical to that referred to in the Manned Bomber study.*

The major cost assumptions regarding this missile are as follows:

(1) Each strategic bomber squadron (15 operational aircraft) would be equipped with 120 FLAM's.

(2) Each base would require air-conditioned storage sites for the missile, at an estimated cost of $1,500,000 per base.

(3) AGE costs for missiles were estimated to be 25 per cent of the AGE procurement costs.

(4) Costs of initial spare missiles and missile spare parts were estimated to be 20 per cent of missile procurement costs.

(5) It was assumed that the FLAM's for the SPA systems would cost 10 per cent more than those for ground-based systems. This 10 per cent was added to cover any additional costs of operating the missile in an underwater environment.

(6) Operating costs include both missile and AGE replacement and maintenance. Missile replacement includes combat crew test firings, missile reliability test firings, and missile attrition. The cost is estimated at five per cent of the missile procurement cost. Missile maintenance was estimated at 20 per cent of missile procurement cost. AGE maintenance and replacement was combined and estimated at 25 per cent of the AGE procurement costs.

(7) For purposes of simplification the missile maintenance personnel were included in the estimate of aircraft maintenance personnel. The number involved was small.

---

*Cost Analysis Department, Weapon Systems Cost Estimates of the Penetrating Manned Bomber Study (U), The RAND Corporation, RM-3073-PR, April 1963 (Secret--Privileged Information).

Table 15 presents the estimated missile costs.

Table 15

FLAM MISSILE COSTS PER AIRCRAFT SQUADRON[a]

(millions of 1964 dollars)

	Submerged Penetrator	AMSA Penetrator	Parasite Penetrator
R&D (including 100 test vehicles	100	100	100
Initial investment			
Procurement missiles and spares	95	86	86
AGE and AGE spares	26	19	19
Other initial costs	12	12	12
Total	133	117	117
Annual operating			
Missile maintenance	12	11	11
Missile replacement	7	6	6
AGE maintaining and replacement	5	4	4
Other annual cost	1	1	1
Total	25	22	22

[a]Assumes a six-squadron force in each case.

VI. UNDERWATER EQUIPMENT COST

The estimates of the underwater equipment costs were derived from a study of tankers and dry cargo ships by Roger Johnson and Henry Rumble.* Table 16 lists the design characteristics and estimated average costs of underwater equipment.

Table 16

	SPA Underwater Equipment		Submersible Tanker Equipment	
	Platform	Pusher Tug	Platform	Pusher Tug
Displacement (tons)				
Submerged	10,000	2,655	16,000	3,060
Light ship	4,700	2,125	4,700	2,450
Dimension (ft)				
Length	356	167	405	176
Beam	54	30	64	32
	27	30	32	32
Speed (kt)				
Without aircraft	20	20	20	20
With aircraft	16	16	16	16
Shaft horsepower	...	14,900	...	18,900
Estimated Average Cost/Item (millions of 1964 dollars)	7.2	39.0	7.2	42.0

To develop the five-year system costs for the submersible equipment, support and other costs were added to the procurement costs as shown in Table 17.

---

*R. P. Johnson and H. P. Rumble, Weight, Cost, and Design Characteristics of Tankers and Dry Cargo Ships, The RAND Corporation, RM-3318-PR, April 1963.

Table 17

SUBMERSIBLE EQUIPMENT--SYSTEM COSTS

(millions of 1964 dollars)

Item	SPA Equipment		Submersible Tanker Equipment	
	Platform	Pusher Tug	Platform	Pusher Tug
PME (see Table 15)	7.2	39.0	7.2	42.0
Other initial investment costs				
Spares (10 per cent)	0.7	3.9	0.7	4.2
Ground support equipment (10 per cent)	0.7	3.9	0.7	4.2
Facilities, training, supplies, and other initial costs (20 per cent)	1.4	7.8	1.4	8.4
Total initial investment	10.0	54.6	10.0	58.8
Annual operating costs (15 per cent x initial investment)	1.5	8.2	1.5	8.8
Five-year system costs (excluding R&D)	17.5	95.6	17.5	102.8
R&D[a]	100.0	100.0	100.0	100.0

[a]Includes procurement test vehicles, systems integration, and test operations.

The percentages used in calculating the "Other initial investment costs" and "Annual operating costs" categories were extracted from budget data dealing with current Navy systems.

The R&D estimate is somewhat speculative and represents the total weapon system test integration and evaluation costs.

The system costs for submersible equipment do not include the cost of any equipment and supplies related to the aircraft. Such costs were included in the aircraft estimate. An additional 10 per cent of the cost of the aircraft was added for equipment that would be located on board the platform: five per cent of this represents the additional initial spare parts, and five per cent represents the additional AGE required for the aircraft. (In a Navy weapon system, this would be called the "shipfill equipment.")

No operational details or support structure were available for any of the underwater equipment, and therefore all cost estimates for such equipment were rough at best.

The moored underwater barges serving as unmanned fuel caches for the flyout systems were considered to be identical in cost to the submersible manned platforms. No design details for these caches were provided, and therefore only a very rough estimate could be made of their costs.

VIII. CONCLUDING REMARKS

Since one of the basic assumptions of this study is that the alternatives examined are equally able to fulfill the penetration and weapons delivery postulated, it seems reasonable for us to discuss them in terms of costs.

Generally speaking, systems requiring a hybrid basing scheme, with penetrator and its support aircraft based differently, tend to be the most costly -- witness the AMSA supported by the submerged tanker aircraft. However, the degree of mobility of the undersea equipment does not seem to have any critical cost implications.

The most critical cost factor for the submersible based systems is the capability of the equipment and personnel to maintain the requisite degree of combat readiness in the underwater environment, an environment with which the Air Force has little experience. The effects of prolonged submersion upon aircraft, missiles, and other equipment need to be known before the operational uncertainties can be dealt with. Since this is such a critical cost area, it would seem to be the first order of business in any further examination of the underwater basing concept.

DOCUMENT CONTROL DATA

1. ORIGINATING ACTIVITY THE RAND CORPORATION	2a. REPORT SECURITY CLASSIFICATION Secret 2b. GROUP III
3. REPORT TITLE System Costs for Strategic Penetrator Systems Using Submersible and Conventional Aircraft (U)	
4. AUTHOR(S) (Last name, first name, initial) Tenzer, Albert J. Watts, A. Frank Kermisch, John J.	
5. REPORT DATE June 1965	6a. TOTAL NO. OF PAGES 70 6b. NO. OF REFS. -
7. CONTRACT or GRANT NO. AF 49(638)700	8. ORIGINATOR'S REPORT NO. RM-4296-PR
9a. AVAILABILITY/LIMITATION NOTICES Security Restrictions Only	9b. SPONSORING AGENCY United States Air Force Project RAND

10. ABSTRACT

A cost analysis of strategic weapon systems comparing aircraft systems capable of undersea operations with land-based systems. Costs are estimated for eighteen systems based on three types of penetrator aircraft. (U) 76 pp. Illus.

11. KEY WORDS

Cost analysis
Submersible aircraft
Aircraft
Systems analysis
Penetration

DEPARTMENT OF THE AIR FORCE
OFFICE OF THE CHIEF OF STAFF
WASHINGTON, DC

13 SEP 2005

MEMORANDUM FOR HQ USAF/XOR

FROM: HQ USAF/XORC

SUBJECT: Mandatory Declassification Review (MDR), Case 05-MDR-054

AF/XORC has reviewed the document pursuant to the subject MDR request. It is our opinion that the document can be declassified in its entirety and provided to the requestor. If you have any further questions or concerns, you can call my action officer, Mr. John Hutto, at (703) 697-0766 or e-mail him with any further questions or concerns.

J.E. Allgood

James Allgood, GS-15, USAF
Deputy, GS-GPA Division